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# Eco-digital storytelling: Engaging historically excluded populations in environmental action through mentoring, geospatial technology, and digital media storytelling

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The environment, science, technology, engineering, arts, and mathematics fields (a collection of fields we call E-STEAM) continue to grow and remain economically and ecologically important. However, historically excluded groups remain underrepresented in science and technology professions, particularly in environmental and digital media fields. Consequently, building pathways for historically excluded students to enter economically viable and ecologically influential E-STEAM professions is critically important. These new pathways hold promise for increasing innovation within these fields and ensuring a multiplicity of representation as these fields are shaped and reshaped to attend to the plural interests of diverse communities. Consequently, this conceptual paper describes an eco-digital storytelling (EDS) approach to engaging historically excluded populations in science, technology, engineering, and mathematics (STEM). This approach offers structured learning opportunities connected to learner interests and community needs with the aim of increasing E-STEAM identity and career interest of teens from groups historically excluded from E-STEAM fields. E-STEAM identity is a meaning one can attach to oneself or that can be ascribed externally by others as individuals interact and engage in E-STEAM fields in ways that foreground the environment. The EDS approach leverages community-based action, technology and digital media, and arts and storytelling as entry points for engaging learners. EDS is designed to increase teens' content knowledge within multiple E-STEAM fields and to provide numerous technology-rich experiences in both application of geospatial technologies (i.e., GPS, interactive maps) and digital media creation (i.e., video, animation, ArcGIS StoryMaps) as a way to shape teens' cultural learning pathways. Examples of rich digital media presentations developed to communicate the EDS approach and local environmental opportunities, challenges, and projects are provided that exemplify how both participation in and communication of environmental action can contribute to more promising and sustainable futures.

KEYWORDS

environmental action, identity, informal learning, storytelling, cultural learning pathways

## 1. Introduction

In this conceptual piece, we introduce Eco-Digital Storytelling (EDS) as an innovative informal educational approach for increasing STEM identity and career interest of teens, especially those from historically excluded groups in STEM fields (e.g., African Americans/Blacks, Hispanics/Latinx, Native Americans/American Indians, non-dominant gender identities and low-income students; historically excluded is used herein). This approach leverages community-based environmental action, technology and digital media, and arts and storytelling as entry points for engaging learners in STEM. E-STEAM[1] identity as used here is a meaning one can attach to oneself or that can be ascribed externally by others as individuals interact and engage in the environment, science, technology, engineering, arts, and mathematics fields in ways that foreground the environment. This approach is grounded in state-of-the-art geospatial and digital media technology and seeks to support high school students in contributing to local environmental solutions as they engage in science communication.

Eco-digital storytelling (EDS) is designed to increase teens' content knowledge within multiple E-STEAM fields (e.g., environmental conservation, geoscience, and science communication) and to provide numerous technology-rich experiences in both application of geospatial technologies (i.e., GPS, interactive maps) and digital media creation (i.e., video, ArcGIS StoryMaps) as a way to shape teens' cultural learning pathways (i.e., the learning that occurs over the lifespan from experiences that are shaped by cultural and community knowledge and values; Bell et al., 2012). Because EDS is grounded in the cultural learning pathways framework and identity authoring is centrally important in this framework, a core component of EDS is career awareness about E-STEAM occupations (e.g., environmental scientist, geoscientist, hydrologist, wildlife biologist, scientific filmmaker/animator and data visualization specialist). This awareness is fostered through: (1) on-the-ground environmental action projects in partnership with community partners, shown by our previous research to strengthen STEM identity (Rodriguez, 2020; Rodriguez et al., 2020; Campbell et al., 2021), and (2) formal training about E-STEAM career pathways through career panels during design charrettes that offer networking opportunities with E-STEAM professionals.

As will be revealed, the innovative nature of EDS is its primary focus on inclusivity, identity authoring, and career interest through expansive forms of participation by those historically excluded in E-STEAM fields. More specifically, EDS involves the innovative use of technologies like geospatial and digital media technologies, authentic real-world learning experiences *via* meaningful and relevant environmental action projects, a focus on workforce development as competences and performances are understood and used in close collaboration with E-STEAM professionals, and partnerships among teens, educators, community conservation organizations, and near-peer mentors to envision and create more just, equitable, and sustainable futures.

## 2. A need for innovative informal E-STEAM programming

In the United States, the National Science and Technology Council Committee on STEM Education emphasizes the critical need for a diverse talent pool of STEM-literate Americans to support essential sectors of the economy and for making scientific discoveries and creating technologies of the future (MacIsaac, 2019). Beyond this, there is a need to ensure a heterogeneity of perspectives beyond Western ontologies (e.g., Indigenous relational ontologies) are considered for navigating societal issues and imagining plural possible and thriving futures that center a multiplicity of perspectives and interests (Bang and Marin, 2015; Pugh et al., 2019; McGowan and Bell, 2022; Pierson et al., 2022). Additionally, research indicates that demographically diverse groups are more likely to be cognitively diverse and innovative than homogeneous groups (van der Vegt and Janssen, 2003). As well, people from historically excluded groups have untapped talent with potential to positively influence innovation in the STEM workforce, and can help ensure a commitment to preserving and sustaining thriving diverse and plural lifeways that

1 We use STEM and E-STEAM throughout the paper; however, we note that they are not being used interchangeably. We use STEM (i.e., science, technology, engineering and mathematics) when discussing literature that explicitly focuses on STEM fields or learning environments alone. We use E-STEAM to refer to the collection of environment, science, technology, engineering, arts, and mathematics fields. We do so in order to emphasize a "practice turn" that positions learners to engage in the epistemic practices of these disciplines in order to achieve specific, community-focused, transdisciplinary goals (e.g., engaging in investigations to better understand environmental injustices not as a matter of science alone but also as a sociopolitical matter requiring action). Thus, the use of E-STEAM elevates the need for an epistemic framework and associated practices that must be foundationally transdisciplinary and potentially generative of meaningful social change (Mejias et al., 2021).

are vital to societal wellbeing and essential for a more just society (Philip and Azevedo, 2017).

Employment opportunities in E-STEAM fields are growing rapidly. From 2007 to 2017, STEM jobs grew by 24%, compared to 4% in other occupations (Noonan, 2017). Within STEM fields, environmental jobs are expected to increase by 8% between 2019 and 2029, compared to 4% for other occupations (Bureau of Labor Statistics, 2021). Additionally, both STEM and Arts sectors are critical to economic vitality, e.g., STEM jobs account for >50% of United States economic growth over the past 50 years (Babco, 2004); annual economic growth rate of the Arts sector doubles that of the total United States (Hutter, 2019). Nevertheless, as E-STEAM fields grow and remain economically and ethically important, historically excluded racial and ethnic groups[2] remain underrepresented in science and technology professions, with representation (13.3% of 2017 science and technology employees) well below that of the general population (28.1% of 2017 United States population), particularly in environmental and digital media fields (Rothwell, 2012; National Science Board and National Science Foundation, 2020). As such, building pathways for students from historically excluded groups to be prepared and qualified to enter economically viable E-STEAM professions is both ethically important and critical to increasing innovation within these fields and ensuring a multiplicity of representation as these fields continue to be shaped and reshaped in transformational ways to attend to the plural interests of diverse communities. More specifically, the development of pathways for students from historically excluded groups that are situated in the context of an ethical commitment to plurality can counter the hegemonic push for a 'One-World World' (Law, 2015) that, through universalizing practices,[3] has historically erased the contributions of diverse individuals and populations (Liboiron and Lepaswky, 2002).

While the factors influencing participation in E-STEAM fields are complex, inequities prevalent within formal education in the U.S. are one major barrier. Educational opportunity and quality disparities between White and historically excluded students are well documented nationwide (National Research Council, 2009, 2012) and prevalent in both urban and rural settings (Logan et al., 2012). These educational inequities for historically excluded students result in profound differences in STEM academic performance that have changed little from 1992 to 2017 (de Brey et al., 2019).

## 3. Theoretical framework for the E-STEAM programming and the eco-digital storytelling approach

The overarching theoretical framework for conceptualizing E-STEAM programming more generally, and the Eco-Digital Storytelling approach more specifically, is the importance of cultural learning pathways, which are the amalgam of learning that occurs over a lifespan as learners engage with various experiences (e.g., informal learning, schools, community interactions) that are shaped by cultural and community knowledge and values. The ranges of experiences learners choose to pursue are shaped by their interests, concerns, social relationships, and identity (Bell et al., 2012). Cultural learning pathways are critical to identity authoring, which is grounded in social practice theory (Carlone, 2012) and recognizes that people are formed in practice. The EDS approach aims to impact identity authoring. We define identity, in alignment with Beijaard (1995), as "who or what someone is, the various meanings someone can attach to oneself, or the meanings attributed to oneself by others" (p. 282). In support of identity authoring as learning in social practice, Lave and Wenger (1991) proposed that learning is an outcome of practice and discourse. In other words, learning happens in the context of engaging in pursuits of consequence (e.g., community-based, environmental action projects) through the use of disciplinary concepts and practices (e.g., environmental science field techniques) to work at solving problems (e.g., managing invasive species in local wildlife management areas). Similarly, Carlone and Johnson (2007) note how identity work can be thought of as learning since the following three empirically accessible dimensions are central to identity authoring: (1) Competence: knowledge and understanding of science [E-STEAM] content; (2) Performance: social performances of relevant scientific [E-STEAM] practices, e.g., ways of talking and using tools; and (3) Recognition: recognition by oneself and by others (p. 1191).

With the cultural learning pathways framework, this model of identity authoring proposed by Carlone and Johnson (2007) draws on Gee's (2001) theory of identity that focuses on the "kind of person" one is seeking to be and enact in social settings. In this, Gee notes how one cannot successfully enact a particular identity that is recognized as credible by others without drawing on relevant competences and practices that are suited for meeting group-level needs in a particular context. Consequently, the importance of EDS lies in how historically excluded teens are supported to find success within the context of E-STEAM in ways that shape their cultural learning pathways. This is accomplished through engaging in interest-driven community-based environmental action projects that draw on teens' rich cultural and linguistic resources.

2 The historically excluded groups examined in the cited research primarily include African Americans/Blacks, Hispanics/Latinx, and Native Americans/American Indians. As such, when we refer to 'historically excluded' groups in our work we also extend this to non-dominant gender identities within E-STEAM fields and students from socioeconomic minority groups.

3 Liboiron and Lepaswky (2002) point out how universalizing practices 'invisibilize' the power of the Eurocentric narrative as the neutral and global perspective or the 'One-World World' (Law, 2015). This can be seen, for example, as the Anthropocene is framed as human caused, even when it is clear that Western and industrialized societies (i.e., some humans and not others) have played an outsized role in contributing to climate change.

## 4. Literature supportive of E-STEAM programming

Informal E-STEAM education programs can provide a means to increase equity and accessibility of E-STEAM learning experiences and to integrate more experiential, place-based, and culturally-sustaining instructional approaches that make E-STEAM learning inclusive and motivating for diverse student populations (National Research Council, 2009). In particular, diversity pathway programs (programs that seek to facilitate historically excluded students' navigation of their E-STEAM career paths) are most effective in broadening participation when multiple pathways of exposure and engagement are used, such as coupling academic opportunities, mentoring, internships, community action projects, career exposure, and networking [Ilumoka et al., 2017; Taylor, 2018; Taylor et al., 2018; Morales and Jacobson, 2019; National Academies of Sciences, Engineering, and Medicine (NASEM), 2019]. Additionally, studies have demonstrated how historically excluded students' success rates increase significantly when they have access to mentors of the same race or ethnicity [Ong et al., 2011; Taylor et al., 2018; National Academies of Sciences, Engineering, and Medicine (NASEM), 2019]. These approaches positively impact E-STEAM self-eficacy, attitudes towards E-STEAM issues, perceived rewards of E-STEAM careers, and social support for pursuing E-STEAM careers [Quimby et al., 2007; Ilumoka et al., 2017; National Academies of Sciences, Engineering, and Medicine (NASEM), 2019]. Consequently, our conceptual work is situated in literature related to the need for community action-oriented E-STEAM programs alongside the importance of science communication, storytelling, digital media, geospatial technology, and the combination of geospatial technology and digital media.

### 4.1. Need for community action-oriented environmental-STEAM programs

Broadening participation in community-based environmental action can expand the capacity to address emerging environmental issues (Horwich and Lyon, 2007; Ohmer et al., 2009; Short, 2010; Krasny, 2020), cultivate science-literate and civically engaged community members (Schusler et al., 2009; Short, 2010; Krasny, 2020), and promote positive youth development, recognition, and academic achievement (Schusler and Krasny, 2010; Schusler, 2015). Environmental action programs support participants as they deliberately contribute to decision-making through understanding and using E-STEAM competences and performances, planning, implementation, and reflection of efforts intended to achieve a specific environmental outcome situated within a community (Emmons, 1997; Schusler et al., 2009). This participatory and action-oriented approach enables learners to reflect upon and address social aspects of environmental problems that are relevant and meaningful to them (Schusler and Krasny, 2010). Examples of environmental action include developing urban gardens in vacant lots to provide fresh produce to the community, controlling erosion along stream banks in response to high sedimentation levels, and monitoring black bear activity patterns in public areas to educate the community about wildlife–human interactions (Cisneros et al., 2021).

Researchers and practitioners have identified numerous benefits of community environmental action at individual and community levels. These outcomes include promoting civic and professional development, fostering self-eficacy, developing a sense of place and nature connectedness, building social capital, and contributing to improvements in environmental quality (Schusler et al., 2009; Short, 2010; Krasny, 2020). In particular, teen-led community environmental action projects afford students opportunities to integrate their culture and background to address real-world E-STEAM issues, thus connecting their lived experiences to E-STEAM content areas and developing their agency and recognition as E-STEAM contributors (Morales-Doyle, 2017; Madkins and Mckinney de Royston, 2019). Indeed, our previous research evinced how community environmental action projects can significantly and positively impact learners' STEM identities in the context of completing community environmental action projects (Rodriguez, 2020; Rodriguez et al., 2020; Campbell et al., 2021).

### 4.2. Importance of science communication, storytelling, and digital media

The ability of scientists to communicate science to non-scientists is fundamental to public science literacy and, as the COVID-19 pandemic has shown, public policy. As such, understanding the importance of reliable, effective, and engaging science and environmental communication is a critical performance for the emerging E-STEAM workforce. However, science students generally are not adequately prepared as communicators (Brownell et al., 2013), and current methods of science communication often incorporate jargon-laden content presented in traditional formats (e.g., conference presentations, scientific journal articles) that are not easily accessed or digested by non-expert audiences. In addition, science communication often fails to draw on the expansive cultural and linguistic perspectives that historically excluded students bring to E-STEAM learning experiences (Brown, 2020).

With its broad reach, digital media (e.g., video, animation, websites, and social media) offers a key opportunity to communicate science that can be quickly digested by broad audiences. Given digital media platforms' accessibility, community scientists of all ages and backgrounds can be recognized as persons contributing to E-STEAM pursuits as they communicate their environmental action efforts through their own narratives. In this regard, online digital media provides a pathway to embrace, legitimize, and recognize the rich cultural and linguistic narratives of populations historically excluded in E-STEAM (Gould et al., 2018).

Combining digital media with storytelling to create what we call Eco-Digital Storytelling can further public engagement with environmental science, while concurrently reinforcing E-STEAM career interests and identity authoring as part of learners' cultural learning pathways (Bell et al., 2012). Storytelling provides an effective method to articulate and understand complex concepts. The large spatial and temporal scales of environmental science, which are challenging for any individual to grasp, can be connected to a more comprehensible human scale through digital storytelling and visualization (Hubley and Schwartz, 1946; Jones et al., 2007; Moezzi et al., 2017). In fact, studies have shown that scientific storytelling is useful to develop trust with and increase retention of knowledge and willingness to learn and take action by broad audiences (Sundin et al., 2018). As community scientists begin to tell their environmental action stories, they also tell their personal stories of their place in the community and in E-STEAM fields, amplifying voices that are often left out.

### 4.3. Using geospatial technology for understanding environmental issues

Geospatial technologies are used to visualize, measure, and analyze features or phenomena that occur on the earth, including its landforms, climate, and infrastructure. Geospatial technologies include geographic information systems (GIS), global position system (GPS), remote sensing, and image analysis. In environmental science, these technologies facilitate the collection and analysis of spatial and temporal data to identify environmental trends and projections (e.g., climate change modeling), as well as to assess the interconnectedness of economic, social, political, and ecological relationships. Encouraging the development of geospatial literacy helps students to develop competence connected to E-STEAM and to understand how location and geography affects perspectives, power, and environment (Langran and Baker, 2016). Furthermore, an increase in demand for mapping and GIS services is projected between 2018 and 2028 (U.S. Department of Labor, 2019), representing a technology job sector with critical need for quality workforce training. Advances in geospatial technology over the last decade represent a true paradigm shift (Dangermond and Goodchild, 2020), as it has enabled location-based GPS services to permeate our day-to-day activities and integrate into most consumer devices, from smartphones to drones. Smartphones and other mobile devices can be used for location-specific environmental data collection. Recreational and consumer-grade drones are now inexpensive and easy to fly, allowing everyday users the ability to collect remotely sensed aerial imagery that can serve a variety of purposes.

### 4.4. Combining geospatial technology with digital media

Although geospatial technology is an essential tool for supporting environmental decision-making, mainstream adoption of these technologies in educational settings has historically been relatively isolated and inconsistent (Kerski, 2003). ArcGIS StoryMaps are a notable exception that has been effective in education (Cope et al., 2018) and science communication (Patterson and Bickel, 2016). A StoryMap is a web-based storytelling platform that facilitates the integration of descriptive narratives alongside interactive GIS maps and embedded digital media, including images, videos, and interactive content. Over one million StoryMaps have been authored all over the world, sharing narratives about human conflict, progress in solving environmental issues, and historical heritage, among other topics (Dangermond and Goodchild, 2020). Thus, StoryMaps provide a platform that allows both professionals and community scientists to harness the power of interactive online maps and digital media to create a dynamic and compelling means of communicating science to a range of audiences. StoryMaps are also helping to connect people to scientific findings and studies by providing an interactive way for users to explore broad concepts in a hyper-localized way. Given this, ArcGIS StoryMaps serve as a web-based storytelling platform that supports the incorporation of digital media in telling the story of environmental action projects in the EDS program and as key competences and performances of modern E-STEAM programming important in identity authoring.

## 5. The eco-digital storytelling approach as an example of needed E-STEAM programming supportive of historically excluded populations' engagement in environmental action

### 5.1. The uniqueness of the eco-digital storytelling program

The educational innovations we propose as part of the EDS program differ from existing STEM educational practice in several ways. A primary focus is on inclusivity, identity authoring, and career interest through expansive forms of participation by those historically excluded in E-STEAM. Building on the success of our previous related work, we draw on strategies for connecting projects to the interests and identities of teens and community partners (Cisneros et al., 2021). The focus on geospatial technology gives participants access to local spatial and temporal data that support place-based community exploration, environmental action work, and community decision-making. By including Eco-Digital Storytelling and focusing on E-STEAM (i.e., including "Art" in E-STEM programs), we aim to cultivate transformative participation *via* connections to other outlets of cultural expression and knowledge production (e.g., art and storytelling) that historically excluded populations have found to be opportunities for self-expression in cultural spaces outside of historically exclusionary STEM knowledge production spaces (Lippi-Green, 2004; Brown, 2020).

In the EDS approach we plan to recruit historically excluded students by focusing recruitment on educator-student "pods," as teachers often serve as a pivotal entry point and trusted individual to historically excluded students that may not otherwise self-select to participate in an informal science program (Benavides et al., 2016). Additionally, recruitment efforts focus on partnerships with underserved and racially diverse communities (i.e., areas where recruitment is planned are more racially diverse and experience higher rates of poverty when compared to state-wide averages).

As can be seen in Figure 1, participants in the EDS approach will engage as members of school pods—groups of 5–6 historically excluded high school students and their teacher—supported across the program by undergraduate near-peer mentors, community partners, and university faculty. The EDS approach begins as school pods attend two immersive workshop field trips in late fall at the University of Connecticut's main campus where they (1) discover how geospatial technology can be used to investigate local environmental issues (Chadwick et al., 2018), and (2) explore and engage in digital storytelling. Considerable time during the workshops is also dedicated to guiding school pods through brainstorming and designing local environmental action projects tailored to their interests and their community's needs using project support resources (e.g., project planning templates, communication best-practices, references to past student projects; Cisneros et al., 2021).

After the workshops, school pods, in collaboration with their network of support (see Figure 2) carry out community environmental action projects that employ one or more of the geospatial and digital media tools/techniques learned during the workshops. Guided by the undergraduate near-peer mentors, school pods build their environmental action stories using a variety of approaches, including developing explanatory illustrations, spatially-referenced video footage for interactive maps, digital animations that explore an environmental topic related to their project or that encourage a community call to action, and short films that document their environmental action project process or highlight connections between their environmental action project and their communities.

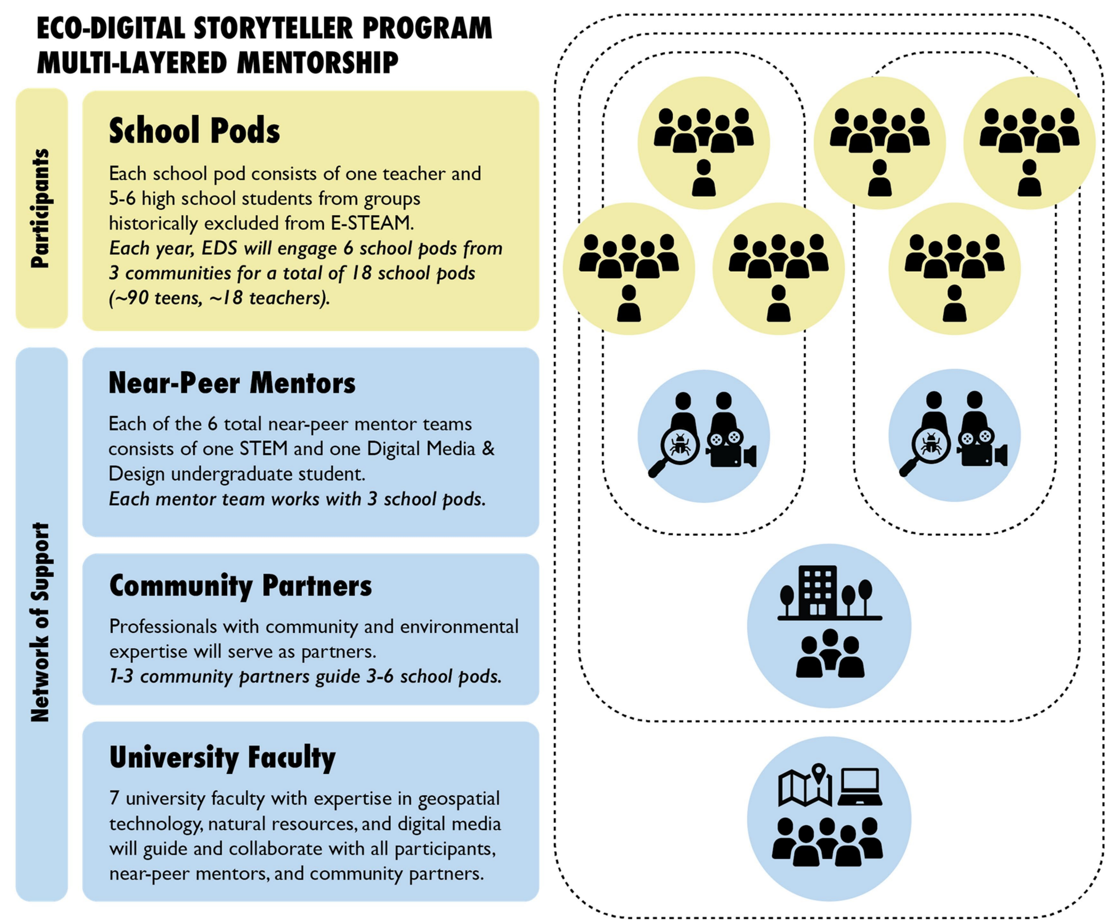


FIGURE 1
EDS mentoring and collaborations.

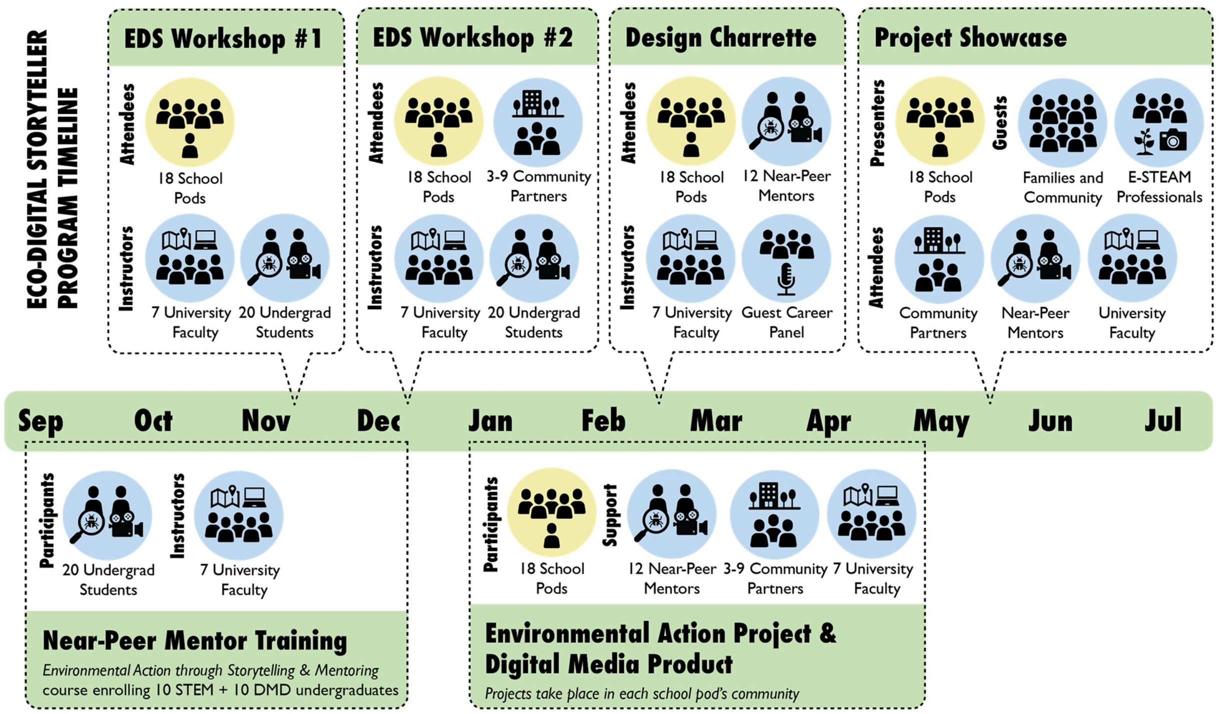


FIGURE 2
Program elements of EDS.

In late winter, school pods reconvene with program faculty, near-peer mentors, and community partners for a one-day design charrette at the university to share status updates and remaining plans for their environmental action projects to the full group for feedback. The design charrette event also includes a panel on E-STEAM career opportunities where students connect with professionals (e.g., environmental scientist, geoscientist, natural resources manager, hydrologist, forester, wildlife biologist, and scientific filmmaker/animator or data visualization specialist) who provide input on their projects. The EDS approach culminates in effective digital environmental storytelling when school pods showcase their community projects in the spring at a statewide conference or other public forum (e.g., town planning meetings, film festival) and online platforms (e.g., website, social media, and StoryMaps website).

The EDS program structure, theoretically grounded by the cultural learning pathway framework, was co-designed with educators and community partners from underserved school districts to create an equitable, inclusive and culturally-sustaining program. As such, EDS integrates multi-layered mentorship from individuals that represent different points along an E-STEAM career trajectory (i.e., near-peer undergraduate mentors and professional community conservation partners; Figure 1), and when possible, matches the race/ethnicity/gender identities of the students (Ong et al., 2011; Taylor, 2018). The EDS program also provides students with a long-term opportunity across the varied program elements (i.e., workshops, community environmental action project, design charrette, career panel, showcase) over the academic year (Figure 2). To minimize conflicts with students' family or job responsibilities, strategies like planning EDS activities during school days and limiting engagement of participants to the academic year instead of during the summer are employed. Finally, the EDS program provides a pathway for teen program alumni to continue E-STEAM participation and career preparation in a leadership capacity as undergraduate near-peer mentors, allowing advancement opportunities by participant alumni (an important factor influencing environmental students' entry into environmental careers; Taylor, 2018). The specific ways in which the cultural learning pathways theoretical framework grounds the experiences of learners in the EDS program can be seen as participants' interests, concerns, social relationships, and identity are centered and further formed in social practice through the educational innovations outlined. This can be seen as learners are supported to find success in developing competence (e.g., nuanced understandings of local environmental issues) through engaging in performances (e.g., using the ArcGIS StoryMaps platform to convey complex issues as part of integrating spatial data and rich digital media) and being recognized by themselves and others (i.e., undergraduate near-peer mentors, community partners and community members, university faculty) as a result of their interest-driven community-based environmental action projects that are communicated through digital environmental storytelling.

Building on our previous related research (i.e., Chadwick et al., 2018; Rodriguez et al., 2020, 2021; Campbell et al., 2021; Cisneros et al., 2021) both as a foundation of the design of the EDS approach and to support our ongoing assessment and research, we investigate the effectiveness of supporting participants' E-STEAM interests and intersecting identity authoring in connection to their cultural learning pathways. To do this, we draw on previously created surveys that have been shown to be valid and reliable in detecting changes in STEM career interests and identity and close qualitative case studies. To assess and understand participants' career interest, we draw on Kier et al.'s (2014) STEM Career Interest Survey developed to leverage social cognitive career theory to effectively examine interest in STEM careers. We investigate changes in identity using our previously developed Conservation Science and Technology Identity Survey (Rodriguez et al., 2020, 2021) designed as an empirical way to measure STEM identities and the intersection of identity constructs such as competence, performance, and recognition. Each of these surveys is collected at multiple time points throughout participants' involvement in the EDS program (i.e., prior to, after the initial workshops, and at the conclusion of their involvement). As part of our close qualitative case studies, we follow 2–5 school pods yearly to better understand their interests, the performances in which they engage, the ways in which competences are communicated, and how recognition unfolds—in relation to near-peer mentoring, digital media storytelling, and geospatial technologies. Our past research, where we supported 221 participants to conduct 96 meaningful local conservation projects since 2017, evinced how community environmental action projects can significantly and positively impact learners' STEM identities (Campbell et al., 2021; Rodriguez et al., 2021). Additionally, our qualitative case study research revealed the nuance of how individuals who are supported to recognize and use their resources while engaged in conservation projects with meaningful others (e.g., adult partners, scientists, and community members) helped maintain and strengthen their STEM identities (Campbell et al., 2021; Rodriguez et al., 2022).

## 5.2. Key features of the eco-digital storyteller program

The EDS program was designed around the following key features:

### 5.2.1. Innovative use of technology

We introduce teens to geospatial and digital media technologies and support technology application through on-the-ground community environmental action projects and creative, engaging science communication.

### 5.2.2. Innovative learning experiences

We engage EDS participants in a program that provides both technical training *via* two full-day workshops and one-day design charrette, and authentic real-world application experiences *via* a meaningful and relevant environmental action project. These program components are enriched by a multidisciplinary E-STEAM network of support consisting of instructors, near-peer undergraduate mentors, and community conservation partners.

### 5.2.3. E-STEAM literacy and workforce development

The approach is designed to catalyze, facilitate, and support projects that strengthen teens' E-STEAM competencies and performances, part of E-STEAM literacy, in authentic real-world applications. Involvement in community environmental action projects allows students to develop both E-STEAM literacy (e.g., E-STEAM competences and performances) and technical and job skills (e.g., teamwork, communication) in preparation for becoming a civically-minded member of the E-STEAM society and workforce capable of imagining and supporting community and environmental thriving. Teens also learn how technical skills and knowledge are applied in societal issues as part of civic life and environmental, geospatial, science communication, and digital media technology careers. Finally, students receive training about career pathways in these career fields through a career panel during the design charrette and through collaboration with E-STEAM professionals throughout the program.

### 5.2.4. Strategies for broadening participation

Bio-science (STEM) and digital media and design (DMD) undergraduate students historically excluded from E-STEAM fields are recruited to serve as near-peer mentors to historically excluded teen participants, and promote the inclusive E-STEAM narratives of historically excluded teen participants *via* digital media storytelling (a culturally-sustaining approach). The near-peer mentors serve as a key leader within the network of support for each school pod. The near-peer mentors are recruited using a comprehensive recruitment strategy to ensure that the course and near-peer mentor opportunity reaches all potential candidates, with particular focus on historically excluded STEM and DMD undergraduate students. The recruited near-peer mentors will enroll in a 3-credit interdisciplinary course, collaboratively developed, and taught by STEM & DMD faculty (the EDS team). The course teaches: (1) an introduction to environmental science issues relevant to local communities, (2) an introduction to story development and effective visual storytelling techniques, (3) application of geospatial technology in environmental science efforts and storytelling *via* ArcGIS Online, and StoryMaps, (4) use of digital media for environmental storytelling (e.g., video, animation) produced using mobile devices, DSLRs, Adobe Creative Cloud, and other free/open-source software, and (5) culturally-sustaining mentorship approaches to facilitate collaborative and inclusive team norms. During the interdisciplinary course, about 2.5–3 weeks of classes are dedicated to culturally-sustaining pedagogy (CSP) mentorship approaches. More specifically, undergraduate students in the course will engage in these topics through an interactive learning module that highlights CSP approaches like self-documentation and community asset-mapping and guest speakers with CSP experience and expertise (e.g., authors from Paris and Alim's (2014) *Culturally Sustaining Pedagogies*). During the course, STEM-DMD students will work collaboratively with course instructors to apply course content to co-facilitate the two on campus EDS workshops and develop materials that will assist school pods during their environmental action projects.

### 5.2.5. Develop strategic partnerships

The EDS approach aims to forge unique E-STEAM partnerships among high school students, educators, community conservation partners, and historically excluded near-peer mentors that facilitate transformative and impactful environmental and digital media experiences. As teens share their community projects as part of the school pods showcase in the spring at a statewide conference and other public forums and online platforms, they are further recognized for their facility to engage in and shape participation in E-STEAM fields.

## 6. Examples of eco-digital storytelling projects

Environmental action projects may cover a range of topics (e.g., food scarcity and urban gardens, water quality issues from stormwater runoff, community natural resource inventories, climate change adaptation in coastal towns, invasive species mapping and removal, mapping trails and green spaces, wildlife monitoring of species of ecological importance). The following are rich examples of a community action-oriented environmental-STEM project and a digital medial design project. Both examples culminated in storytelling, maps, and digital media that exemplify facets of the EDS approach.

### 6.1. Beavers of Mendell's Folly

This project was carried out by an intergenerational (teen-adult) team who participated together in the Conservation Training Partnerships (CTP), a place-based environmental action program hosted by the University of Connecticut (Cisneros et al., 2021) that served as a basis for the development of the EDS approach. CTP begins with a two-day training workshop that introduces participants to natural resource science concepts such as land use change, water resources, and biodiversity. Teams are then guided through planning and implementing variable-length local conservation projects tailored to their interests and their community's needs. The adult partner of this team was a land trust volunteer and her teen partner's former middle school teacher. The goal of their conservation project was to highlight and communicate the importance of a beaver-created wetland at Mendell's Folly, a local land trust property. Through scientific literature research and contacting topic-area experts, they exemplified the third design principle of the CTP program—connect the project to disciplinary knowledge and practice, a design principle that is also central to the EDS approach. For example, to gain insight and understanding about the role of beavers as ecosystem engineers, they toured the University of Connecticut's Biodiversity Research Collections and interviewed both a graduate student studying wetlands and a biologist at a nearby nature center. Applying geospatial technology skills learned during the CTP workshop, the team created an ArcGIS StoryMap to tell the story of the wetland at Mendell's Folly. As readers explore and interact with the StoryMap, they learn how beavers have changed the wetland over time, the numerous benefits that wetlands provide, and the diverse wildlife species that depend on wetlands. Embedded throughout the StoryMap are narrative text, digital media (e.g., photos and videos), and maps intended to engage and inspire a broader audience. Visitors to Mendell's Folly will discover an eye-catching educational sign (Figure 3) near the wetland overlook developed by the teen member of the project team that contains information, graphics and a scannable QR code to access the award-winning StoryMap (Lu and Arnini, 2020; access the StoryMap at: https://storymaps.arcgis.com/stories/e7eed03bfb274d8daa96842b7315fb3).

### 6.2. Designing for intergenerational community conservation: Digital media design collaborations

Another collaboration that served as a basis for the EDS approach was initiated in the spring of 2019 as CTP project leadership (Cisneros et al., 2021) reached out to elicit help from colleagues/faculty members (co-authors of this paper) in telling the story of the CTP program, with the ultimate aim of producing a brief video that could be presented at the 2020 STEM For All Video Showcase sponsored by the National Science Foundation (NSF). The video showcase disseminated NSF-funded projects' approaches to learning from research to practice as video contributors engaged with showcase visitors through facilitated discussion board interactions around funded projects. Much the same way the EDS approach seeks to pair undergraduate near-peer mentors with high school pods to support communicating about environmental action projects through digital media storytelling, this project involved identifying a Digital Media Design (DMD) undergraduate student to partner with the CTP leadership team to (a) attend summer workshops to capture video and interview footage, (b) explore the use of archival video footage and previously created digital media content, (c) engage CTP leaders to learn more about the program and its priorities as a basis for producing the story, (d) engage in iterative storyboarding with the leadership team to propose and refine the story, and (e) produce and share the project video. Similar to how the EDS approach culminates in teams showcasing their work at statewide environmental conferences or other public forums (e.g., town planning meetings and film festivals), this project culminated in


FIGURE 3
Mendell's Folly education sign.

sharing the story of the CTP program and its participants' experiences at the 2020 STEM For All Video Showcase (see CTP video at: https://stemforall2020.videohall.com/presentations/1788). In the end, the video showcase included almost 700 presenters and co-presenters who shared videos about 171 different projects. Additionally, 56,500 visitors from over 140 countries interacted with the video showcase over the week-long period, where there were over 6,000 discussion posts related to the 171 presentations. As further evidence of the video's positive reception, the CTP project video was named as one of 12 Public Choice award winners. The video showcase supported the CTP leadership team in accomplishing its aim of telling the story of CTP, while also providing a model of how DMD mentorship can help facilitate effective digital media storytelling. The video also afforded recognition to the program leaders and the DMD mentor/undergraduate in the same way the EDS approach aims to support the recognition of high school teachers and student pods as they seek to make a difference through developing ideas about the type of environmentally thriving community they want to live in and share those visions by engaging in environmental action projects.

## 7. Conclusion and implications

The immediate outcomes and direct societal benefits of the EDS approach include: (1) increased participation of historically excluded populations in E-STEAM fields; (2) culturally-sustaining and inclusive informal E-STEAM education and educator development; and (3) increased public scientific literacy and public engagement with science and technology. Specifically, the EDS program provides training in innovative geospatial and digital media science storytelling to historically excluded teens, educators, and undergraduate student near-peer mentors. Through digital storytelling, the EDS program aims to uplift the rich cultural and linguistic narratives of historically excluded participants as they author identities that include E-STEAM and share their E-STEAM community environmental action efforts as part of their developing cultural learning pathways. Highlighting these creative digital products *via* multiple platforms expands the value of the proposed project far beyond the local communities in which they unfold, with the potential to reach a global audience, thereby amplifying and recognizing the voices of historically excluded community scientists as they contribute to sustaining and thriving plural futures in their local communities.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

LC, NF, CC, and DD developed the ECD program, with guidance by TC, AL, HE-F, and B-YP. TC and LC developed the theoretical framework. AL and HE-F were responsible for integrating a focus on digital media, while AL, HE-F, CC, DD integrated a focus on storytelling. CC led the integration of geospatial technology within the ECD program. LC and TC led the writing of this paper, with additional significant contributions from AL, HE-F, CC, DD, and B-YP. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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